



10/526027
PCT/AU03/01131

REC'D 17 SEP 2003

WIPO

PCT

BEST AVAILABLE COPY

Patent Office
Canberra

I, JONNE YABSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2003902374 for a patent by SHIELDLINER CO LIMITED as filed on 16 May 2003.



WITNESS my hand this
Tenth day of September 2003

J R Yabsley

JONNE YABSLEY
TEAM LEADER EXAMINATION
SUPPORT AND SALES

**PRIORITY
DOCUMENT**

SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH RULE 17.1(a) OR (b)

ORIGINAL
AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Invention Title: Apparatus for and Method of Lining Conduits

The invention is described in the following statement:

"Apparatus for and Method of Lining Conduits"

Field of the Invention

This invention relates to an apparatus for, and a method of, lining ducts and other conduits.

The invention has been devised particularly, although not solely, for internally lining fluid flow conduits and is applicable to both gravity flow pipes, such as sewer and stormwater drainage, and pressurized systems such as water and gas pipes.

The invention is applicable to the renovation of existing pipelines and other conduits in various states of deterioration, from impaired hydraulic performance to partial or complete loss of structural integrity with a total failure to contain the fluids within or stop the ingress of fluids from without the pipe.

Background Art

Throughout the world, there are numerous pipelines which are approaching or have exceeded their service life, have been installed in extreme environments or were incorrectly installed. Consequently, they have deteriorated to an extent that remedial action is required in order to maintain the effectiveness of the pipeline or to avoid leakage. This is particularly so for municipal infrastructure involving pipe networks such as sewers and water mains using materials such as vitrified clay (VC) and reinforced concrete (RC). Typical structural problems with such gravity flow pipes include cracking or poor jointing leading to water ingress, sewage egress, root intrusion or calcification build-up on the pipe walls. The structural problems include longitudinal cracking and circumferential cracking, leading to ovality or partial collapse of the pipe.

Systems used for the renovation of such conduits generally fall within three broad categories. The traditional methods include manually applied liners and cover shotcrete, grouting and placed thermoplastic liners. The second category includes

placed thermoplastic liners installed automatically, using materials such as uPVC and HDPE and cover mechanically or thermally expanding the thermoplastic liner against the conduit wall. The third category involves the placement of generally thermoset or catalysed or UV radiation energy cured liners which are typically placed through the eversion of an already resin impregnated "sock" generally of fibreglass materials. A newer system employs a resin coating on the surface of a flexible tube of aligned polypropylene fibres. The resin on the surface is, upon eversion, forced into the sides of the pipe, the objective being the creation of a bonded liner to the pipe. This does not in practice provide a successful consistent bonded liner as the requirements for the resin layer or thickness varies dependent upon the holes and cracks as well as other requirements for the use of the resin in the pipe.

One proposal to line existing pipelines is disclosed in US Patent 4,687,677 (Jonasson). The proposal involves introduction of a flexible hose-shaped liner containing a curable plastic material into the pipeline to be lined. The flexible liner is introduced into the pipeline in an uncured state and is pressed out against the inside of the pipeline by means of compressed air. The flexible liner is then hardened in place by exposing the curable thermoset resin material to radiation energy. A somewhat similar proposal is disclosed in WO 92/16784 (Lundmark). In this latter proposal, the hose-shaped liner is introduced into the pipeline by either drawing in the liner or by everting the liner into the pipeline.

A disadvantage of such proposals involving installation of a liner which contains a curable resin material and which can be cured upon exposure to radiation energy or heat is that the liner must be manufactured, prepared and stored under fully-controlled conditions at a production facility remote from the installation site and then transported to the installation site. In addition to the transport storage and handling costs involved with storing the liners, there is also the wastage caused by premature curing of the liners in storage. Further, if premature curing is not detected prior to installation, there is the cost of removing the failed liner and commencing the installation again with a new liner. This can contribute significantly to the cost of a pipe lining operation.

There have been various proposals for lining conduits involving installation of a liner as a tube which is everted into the passageway being lined, and which comprises an inner layer of resin absorbent material surrounded by a membrane. As the tube is everted, uncured resin is applied to the everting face of the tube to impregnate the layer of resin absorbent material which is then presented to the surface of the passageway. The everted tube is held in place by fluid pressure until the resin cures to form a rigid lining on the passageway surface. One such proposal is described in GB 1512035.

With lining proposals involving eversion of a tube comprising a layer of resin absorbent material, it is most important for there to be effective impregnation of the resin absorbent material. EP 0 082 212 attempts to address this need by provision of a vacuum inside the tube in order to remove air from the resin absorbent material at the everting face so that such material is in an optimum condition to receive the resin presented to it, thereby ensuring effective penetration of the resin into the absorbent material. However, the method outlined of providing the application of vacuum to the tube is a cumbersome procedure, involving positioning of a vacuum pipe within the tube when it is in a collapsed condition prior to eversion.

Additionally, the resin is presented to the everting face of the tube in the form of a large plug of uncured resin in the passageway to which back pressure is applied. This is employed to support the plug of resin and drive the plug, and the seal within the pipe, forward. Consequently, it is necessary for the everting tube to push the plug of uncured resin along the passageway, with the result that the plug of uncured resin can be under high and variable pressure. The fact that the plug of resin is under high variable and uncontrolled pressure can cause difficulties, one being that ongoing delivery of replenishment resin to the plug can be complicated. Further, as there is no monitoring present, there is no knowledge of the size or consistency of the volume of resin. In particular, there is no feed back to determine if the volume trapped between the everting tube and the seal is air or resin. Also, with an uncontrolled resin "plug", the air that becomes trapped in the resin volume cannot escape.

It is against this background, and the problems and difficulties associated therewith, that the present invention has been developed.

The reference to prior art in this specification is not, and should not be taken as, an acknowledgement or any form of suggestion that that prior art forms part of the common general knowledge in Australia.

Disclosure of the Invention

According to one aspect of the present invention there is provided apparatus for lining the internal surface of a conduit comprising a body adapted to be progressively moved along the conduit for installing a flexible liner onto the interior surface of the conduit or any substrate applied thereto, the flexible liner comprising a tube undergoing eversion within the conduit, the body presenting a contact surface against which the tube acts during eversion thereof, the contact surface having means for delivery of resin to the everting portion of the tube.

The body may be caused to move along the conduit in any appropriate way, such as for example by application of a driving force thereto (by for example a towline) or pressure applied thereto through the everting tube (arising from the presence of a inflation fluid within the tube), or a combination thereof. Where the body is caused to move by pressure applied through the everting tube, it may be necessary to provide a retarding force to control the rate of advancement of the body. The retarding force may be applied in any appropriate way, such as by a brake sled operably connected to the body and in friction engagement with the interior surface of the conduit.

The means for delivery of resin may include a plurality of ports in the contact surface, the ports communicating with a supply of resin.

The contact surface may be defined by a plate having apertures therein incorporating the ports.

The plate may be rigidly or elastically supported.

The plate may have one face thereof defining the contact surface and an opposed face which provides a boundary for a resin chamber from which resin may be delivered to the contact face by way of the apertures therein. This also assists in the rapid and controllable release of any air trapped within the liner. As the air is purged from the highest point within the chamber all the conduit is filled with resin.

With this arrangement, the pressure exerted by the everting tube is exerted on the contact surface and not onto the resin itself and not in particular on the resin contained within the resin chamber. Consequently, the resin can freely flow into contact with the everting tube and can be easily replenished by delivery of replenishment resin to the resin chamber. In this embodiment the resin pressure remains constant and can thus be controlled through a controlled feed back to resin delivery pumps located typically at a control station at ground level. Typically, replenishment resin is delivered to the resin chamber on a continuous basis during eversion of the tube and is controlled with a feed back loop to control feed rate of the everting tube and resin pressure for consistent progress along the conduit.

Preferably, the body also has provision for applying resin to the surface onto which the liner is presented. As alluded to earlier, the surface to which the liner is presented may comprise the interior surface of the passageway or a substrate applied to the interior surface of the passageway.

In this regard, the body may comprise a circumferential chamber which is exposed to the surface and which contains resin which is wiped on the surface. Where the passageway is of circular cross-section, the circumferential chamber is typically of annular configuration.

Preferably, the circumferential chamber is defined between two spaced apart wiper seals for sliding and sealing contact with the surface, and an inner wall extending between the two seals. The outer periphery of the chamber is essentially defined by the surface to which the resin is applied.

The inner wall may be defined by a flexible membrane. The membrane may be deflected for the purposes of pressurising the resin contents within the chamber. Alternatively and/or additionally, the flexible membrane may be vibrated in order to optimise contact of the resin with the surface.

The body may further comprise one or more additional chambers one adjacent another axially spaced along the body.

Each additional chamber may be defined by two wiper seals and an inner wall extending therebetween.

Where there are adjacent chambers, one wiper seal may be common to both of the chambers. In other words, where there are two chambers one leading another with respect to the direction of travel of the body, one wiper seal may function as the trailing seal for one chamber and the leading seal for the other chamber.

Where there are a multitude of chambers, at least some of the chambers may be utilised for the purpose of applying resin to the surface receiving the liner. In such a case, the chambers preferably operate at progressively decreasing fluid pressures in the direction away from the everting tube.

The wiper seals not only perform a sealing function but also function as wiper applicators for applying the resin in a uniform fashion to the surface.

They also form sealed pressurised chambers between which a differential of pressure can be achieved and maintained, with the highest pressure being exerted in the last chamber wetting the everting tube and the lowest in the first chamber. In this way purge lines from the rear chamber can exhaust into the front chamber driven by the differential in pressure.

In certain circumstances, it may be beneficial to apply a substrate to the conduit prior to the placement of the liner. Such substrates may include repair and/or sealing compounds (eg cementitious or polymer grout) or a layer of material for

enhancing the engagement of the liner with the conduit or the filling of the surface of the inside of the conduit.

The substrate substance can be applied in the same pass as the placement of the everting tube. Alternatively, the process may involve placement of the substrate substance first with a removable or sacrificial liner that inflates to hold the substrate substance into position whilst it hardens. Then during a second pass the everting tube can be added once the substrate substance has hardened enough to absorb the water and provide a dry surface to allow the resin to cure to it.

Where a substrate is to be applied to the interior surface of the conduit, at least one of the circumferential chambers may be utilised for such a purpose. The or each chamber concerned would be adapted to receive the substrate substance. The substrate substance would be applied to the interior surface of the conduit in a similar fashion to the manner in which resin is applied; that is, the substrate substance would be presented to and wiped onto the internal surface of the passageway. Obviously, the or each chamber utilised in the installation of the substrate would be ahead of the chambers utilised in the delivery of resin for the purposes of bonding the liner into position.

Again, the substrate material may be vibrated to optimise deposition of the material onto the interior surface of the conduit.

The body may incorporate a leading section for performing preparatory work on the interior surface of the passageway in order to properly prepare it to receive the substrate substance or resin as the case may be. The leading section may include circumferential brush devices adapted to brush the side wall of the passageway.

There may be a plurality of the brush devices axially spaced one with respect to another to form air pressure chambers therebetween. A differential pressure gradient may exist between the chambers such that a pressure flow is generated from rear most chamber to front most chamber.

The forward portion of the apparatus in the preferred embodiment may also incorporate a collection means for collecting debris within the passageway prior to installation of the liner. The collection means may comprise a suction system for collecting the debris.

Preferably, the tube is delivered to the body in a collapsed condition. With this arrangement, the collapsed tube is preferably opened during the eversion process.

The tube may have a collapsed condition involving at least one re-entrant fold. Conveniently, there are at least two re-entrant folds one adjacent each longitudinal edge of the collapsed tube.

An installation cable (such as a rope) may be provided in the collapsed tube for assisting axial movement thereof while in the collapsed condition. Typically, the cable is used to haul the collapsed tube axially. Interaction between the installation cable and the collapsed tube may arise through a binding action therebetween as a consequence of the tube being collapsed about the cable. The cable may progressively separate from the tube as the latter reverts.

The body may be provided with means to establish a "wet-out" region within the collapsed tube prior to eversion thereof for the purposes of increasing the effectiveness of resin penetration.

This may involve a lance structure projecting outwardly of the contact surface and terminating at a free end, with the collapsed tube embracing the lance structure so that the lance structure is inserted in the tube as it approaches the contact face for eversion thereagainst.

The free end of the lance structure may be configured to spread the collapsed wall of the tube to create a cavity to receive the resin.

To do this reliably it is preferred to further include means to monitor and/or control the speed of progress of the lining tool and the volume/thickness of resin applied

to the conduit and the everting tube. Such means may be part as a quality control system upon which the body may react, or communicate to a remote operator who may provide remote control or through a remote feed back loop to the pressure control to the pumps and the liner pull to vary the speed of advance. This can also control the feed pressure for the resin injection into the everting tube and the inflation pressure of the pressure chamber and the tube as well as the vacuum on the tube. In this way, the apparatus can be self controlling to ensure the optimum rate of progress is maintained. This can then be plotted and the plot provided to the customer.

The lance may incorporate an axial passage for receiving the installation cable as it separates from the tube during eversion thereof.

In another preferred embodiment, the apparatus may further include a temperature measurement device for monitoring the temperature of the conduit/liner which may be in communication with a remote operator. There may also be a feed back loop with the resin supply to control the amount of catalyst to resin ratio to suit it to the temperature and conditions within the pipe. This may also form part of the quality control system.

Preferably, the apparatus further includes means for sensing and/or monitoring selected conditions associated with installation of the liner and varying the installation process as necessary having regard to such conditions. Such conditions may include the delivery rate and composition of the resin, loadings on the everting tube and the surface condition of the conduit.

According to a further aspect of the invention there is provided a method of lining conduits utilising apparatus according to the first aspect of the invention.

According to a third aspect of the present invention there is provided a method of lining a conduit comprising: providing a tube as a liner for the conduit, everting the tube into the conduit whereby the tube has an inner tube portion, an outer tube portion and an everting portion extending between the inner and outer tube portions; causing the exposed face of the everting portion of the tube to slidably

engage a contact surface at which a curable resin is presented to the everting face for impregnation thereof.

Preferably, the method further comprises sensing and/or monitoring selected conditions associated with installation of the liner and varying the installation process as necessary in response to such conditions.

Brief Description of the Drawings

The invention will be better understood by reference to the following description of several specific embodiments thereof as shown in the accompanying drawings in which:

Figure 1 is a schematic sectional view of apparatus according to a first embodiment in operation installing of a liner in a pipeline;

Figure 2 is a fragmentary sectional side view of the apparatus installing the liner in the pipeline;

Figure 3 is a fragmentary perspective view of the apparatus installing the liner in the pipeline;

Figure 4 is a fragmentary sectional view of the trailing end of the installation head;

Figure 5 is a fragmentary sectional view of an intermediate part of the installation head;

Figure 6 is a fragmentary sectional view of the leading part of the installation head;

Figure 7 is a fragmentary sectional side view illustrating a wiper seal forming part of the installation head, with the wiper seal being shown in a normal condition;

Figure 8 is a view similar to Figure 7 with the exception that the wiper seal is shown in a deflected condition;

Figure 9 is a schematic cross sectional view of a tube which provides the liner, the tube being shown in a collapsed condition;

Figure 10 is a fragmentary sectional view of the trailing end of an installation head of apparatus according to a second embodiment;

Figure 11 is a fragmentary sectional view of the trailing end of the installation head of apparatus according to a third embodiment;

Figure 12 is a fragmentary sectional side view of the trailing end of the installation head of apparatus according to a fourth embodiment; and

Figure 13 is a view somewhat similar to Figure 12 with the exception that a suction line within the installation head is shown in an extended condition;

Figure 14 is a fragmentary perspective view of apparatus according to a fifth embodiment;

Figure 15 is a perspective view, shown partly cut-away, of a delivery chamber forming part of the apparatus shown in Figure 14, with the collapsed tube structure shown passing therethrough;

Figure 16 is a sectional side view of the delivery chamber shown in Figure 15;

Figure 17 is a fragmentary view of the apparatus shown in Figure 14, illustrating guide rollers for guiding the collapsed tube structure;

Figure 18 is a cross sectional view of a delivery chamber for apparatus according to a sixth embodiment;

Figure 19 is a fragmentary elevational view of apparatus according to a seventh embodiment;

Figure 20 is a schematic view of a sealing clamping seal mechanism used with the apparatus shown in Figure 19;

Figure 21 is a schematic view of a suction line incorporated in the apparatus shown in Figure 20, with the suction line being shown in a retraced condition;

Figure 22 is a view similar to Figure 21, with the exception that the suction line is shown in an extended condition;

Figure 23 is a schematic end view of a brake slide structure forming part of the apparatus shown in Figure 20;

Figure 24 is a view similar to Figure 23, with the exception that the brake slide structure is shown on a somewhat larger scale;

Figure 25 is a side elevational view of the brake slide structure;

Figure 26 is a schematic side elevational view of apparatus according to an eighth embodiment;

Figure 27 is a fragmentary perspective view of the apparatus shown in Figure 26 installing a liner in the pipeline;

Figure 28 is a fragmentary side elevational view of the trailing end of the installation head of the apparatus shown in Figure 26;

Figure 29 is a view similar to Figure 28, illustrating the apparatus installing a liner without use of a installation cable;

Figure 30 is a schematic cross sectional view of a tube structure for use with apparatus according to any of the previous embodiments, the tube

structure being in a collapsed condition having two opposed re-entrant folds;

Figure 31 is a schematic view illustrating the everting end of the collapsed tube structure shown in Figure 30;

Figure 32 is a schematic view illustrating, for comparison purposes, the everting end of a collapsed tube structure of the type illustrated in Figure 9 of the first embodiment;

Figure 33 is a schematic cross sectional view of a further version of the tube structure in a collapsed condition having a plurality of opposed re-entrant folds;

Figure 34 is a schematic cross sectional view of a still further version of collapsed tube structure;

Figure 35 is a schematic cross sectional view illustrating the tube structure of the type shown in Figure 34 installed within a pipeline to provide a lining therefor;

Figure 36 is a schematic cross sectional view of apparatus used for delivery of the tube structure shown in Figure 34 to a pipeline;

Figure 37 is a schematic elevational view of a production system for manufacturing a tube structure of the type shown in Figure 30;

Figure 38 is a schematic view of a former used in the system illustrated in Figure 37;

Figure 39 is a schematic view illustrating construction of an inner layer of the tube structure;

Figure 40 is a view illustrating the inner layer folding about the former;

Figure 41 is a schematic view illustrating construction of an outer layer about the inner layer to provide the tube structure;

Figure 42 is a view illustrating the former being used to assemble the outer layer of the tube structure about the inner layer;

Figure 43 is a schematic view illustrating construction of an inner layer of the tube structure with an installation cable therein;

Figure 44 is a view illustrating the former being used to introduce the installation cable into the inner layer of the tube structure during construction thereof;

Figure 45 is a schematic cross sectional view of an assembly of umbilicals used for delivery of services to the installation head of apparatus according to any of the earlier embodiments, the assembly of umbilicals being contained within a containment sleeve; and

Figure 46 is a schematic elevational view illustrating assembly of the umbilicals and positioning of the containment sleeve therearound.

Best Mode(s) for Carrying Out the Invention

Referring to Figures 1 to 9 of the accompanying drawings, there is shown apparatus 10 according to a first embodiment for installing a liner 11 onto the interior surface 13 of a pipeline 15. The liner 11 provides a hermetically sealed barrier that is resistant to both corrosion and wear.

In this embodiment, the liner 11 is in the form of an everted tube structure 17. Prior to eversion, the tube structure 17 comprises a first layer 17a of a resin absorbent material such as fibreglass fabric, and a second layer 19 prior to eversion of the tube structure 17, the first layer 17a is innermost and the second layer 17b is outermost to provide a lining around the first (inner) layer. The second (outer) layer 17b is selected according to the demands placed on the liner

11 within the pipeline 15. For example, where abrasion and wear resistance is required, the second layer 17b may be formed of polypropylene. In other cases, the second layer 17b may be formed of polyester (Mylar), nylon urethane rubber or other material appropriate for the intended application.

Upon eversion, the first layer 17a is turned outwardly and presented to the interior surface 13 of the pipeline 15. As will be explained in detail later, a curable resin is applied to the first layer prior to its application onto the interior surface 13 of the pipeline 15. An inflation fluid is delivered into the interior 20 of the everted portion of the tube structure 17 to maintain the tube in intimate contact with the interior surface 13 of the pipeline 15 until the resin has cured, whereupon the resin and fibreglass fabric combine to provide a rigid composite structure which lines the pipeline 15, with the second layer being on the inner face of the composite structure and in contact with subsequent fluid flow along the pipeline.

The apparatus 10 comprises an installation head 21 which is movable along the passageway and which includes a body 23. The installation head 21 is adapted to be progressively moved along the pipeline 15 during installation of the liner.

The body 23 has a leading end 27 and a trailing end 29. In this embodiment, the body 23 is adapted to be pulled through the pipeline 15 by way of a tow line (not shown) connected to the leading end 27 and extending to a station (not shown) located exteriorly of the pipeline.

The tube structure 17 is delivered to, and pulled along, the pipeline 15 in a flattened or collapsed condition and is everted from that condition, as best seen in Figure 1 of the drawings. In the flattened or collapsed condition, the tube structure 17 has two opposed longitudinal side portions 18, 19 and folds 22 therebetween, as shown in Figure 9. In Figure 9, the two longitudinal side portions 18, 19 are shown spaced apart, for the purposes of clarity in the drawing. In practice, the two portions 18, 19 would be in facing contact with each other.

With eversion of the tube structure 17, there is created an inner tube portion 31 and an outer tube portion 32, with the two portions 31, 32 being joined by the everting portion 33.

One end of the tube structure 17 is attached to a rigid installation duct 34 positioned adjacent the inlet end of the pipeline 15. Typically, the tube structure 17 is connected to one end of the duct 34 by way of a clamping collar (not shown) which extends around the tube and sealingly connects it to the end of the duct.

A delivery duct 35 extends between the installation duct 34 and a delivery structure 37 which incorporates a delivery chamber 39. The delivery duct 35 comprises a flexible hose structure which is inflated to provide the duct. An inflation chamber 41 is created through the combination of the interior 20 of the everted tube structure 17, the installation duct 34, the delivery duct 35 and the delivery chamber 39. An inflation fluid (such as air) is introduced into the inflation chamber 41 so as to urge the everted tube structure 17 outwardly in order to position it in contact with the interior surface 13 of the pipe 15 to which it is bonded while the resin applied thereto sets.

The inflation fluid is introduced into the inflation chamber 41 by way of the delivery chamber 39 at the inlet end of the duct 35. The delivery chamber 39 is defined by a housing 43 having an entry end 45 and an outlet end 47 which communicates with the duct 35. The entry end 45 of the delivery chamber 39 is closed to maintain inflation pressure in the chamber, there being provided a fluid seal mechanism 49 in the entry end 45 to allow entry of the collapsed tube. The fluid seal mechanism 49 comprises a pair of sealing rollers 51 positioned in side-by-side relationship to receive the collapsed tube structure therebetween. The sealing rollers 51 are resiliently deformable for the purpose of establishing good sealing contact with the tube structure 17.

The inflation pressure causes the tube structure 17 to evert as the installation head 21 moves along the pipeline 15.

The installation head 21 has a contact face 63 at the trailing end thereof against which the tube structure 17 everts. The contact face 63 is configured to conform to, and guide, the everting portion 33 of the tube structure 17 as it turns between the inner tube portion 31 and the outer tube portion 32. The contact face 63 is defined by a pressure plate 65. A resin chamber 67 is located in the body 23 adjacent the pressure plate 65. The pressure plate 65 provides a boundary for the resin chamber 67 and separates the resin chamber from the everting tube structure 17. Resin delivery lines 69 are provided for delivering resin from a source (not shown) to the resin chamber 67.

A plurality of apertures 71 are provided in the pressure plate 65, the apertures 71 extending from the resin chamber 67 and opening onto the contact face 63 by way of ports 72 incorporated in the contact face 63. With this arrangement, the everting tube wipes over the contact face 63 and so is exposed to resin delivered from the resin chamber 67. The resin from the resin chamber 67 also flows into the space 68 bounded by the pressure plate 65 and the everting tube structure 17 to ensure that the everting tube structure is fully exposed to the resin and travels back down the tube to fill and wet the tube structure as it approaches the pressure plate.

A lance 73 projects rearwardly from the pressure plate 65 and terminates at a protrusion 74 which is received in the collapsed interior of the tube structure 17 between side portions 18, 19 as the tube approaches the installation head 21. The protrusion 74 is of bulbous configuration and incorporates a rounded nose 75 which is presented to the oncoming collapsed tube. The protrusion 74 serves to expand the collapsed tube wall to create a cavity 76 into which resin is delivered by way of delivery ports 77 incorporated in the nose 75 and communicating with a central bore 78 in the lance 73. The central bore 78 receives resin from the resin supply by way of delivery line 80. The design of the lance 73 is such as to provide a base attached to the pressure plate 65 of small circumference and the protrusion 74 of a larger circumference. In this way the lance 73 follows the general shape formed by the tube structure as it is everting, with the everting face itself being the point of highest pressure and the area just before the everting face being a point of low pressure. Therefore, it is easier to form a cavity just behind

the everting face. The cavity 76 into which the resin is delivered creates a "wet-out chamber" within the collapsed tube structure 17 for the purposes of initially presenting resin to the tube structure. The objective of the embodiment in this preferred arrangement is the creation of a long "wet-out" chamber by the hydraulic force of the resin bulging the everting tube. The length and size of the wet-out chamber can be controlled by the resin injection pressure and the inflation pressure within the everting tube structure. The balance to be achieved is the length of the wet-out chamber and the wet-out rate. The longer the wet-out chamber the longer time the resin is exposed to the fibreglass the faster the rate of progress.

In the embodiment, the separation of the resin chamber 67 from the force of the everting tube structure 17 driving and pressing against the rear of the installation head 21 means that the resin pressure need only be enough to fill the depth of the pipe and that this is consistent and can be monitored. Also the content of resin in the chamber can be monitored in various means to ensure that all air is purged from the resin volume.

The installation head 21 further includes a guide structure 81 about which the tube structure 17 passes as it everts. The guide structure 81 comprises a guide ring 82 having a ring body 83 with a central opening 84 therein. The ring body 83 presents a guide surface 85 about which the tube structure 17 turns, with the inner tube portion 31 entering the ring body 83 through the central opening 84 and the everting portion 33 passing around the guide surface 85 such that the outer tube portion 32 leaves from the outer periphery of the ring body.

The guide structure 81 may be configured to avoid, or at least reduce, the tendency for formation of wrinkles and folds in the tube structure 17 as it everts. In this regard, the guide structure may comprise a guide ring structure of the configuration disclosed in PCT/AU01/00563 (WO 01/88338).

The guide structure 81 serves to present the tube structure 17, and in particular first layer of fibreglass fabric, to the contact face 63 for exposure to, and impregnation by, the resin.

The guide structure 81 moves with the body 23 as a result of interaction between the protrusion 74 and rollers 93 mounted on a support structure 95 extending rearwardly from the ring structure, with the wall of the tube structure 17 passes through the gap 97 between the rollers and the protrusion 89. Consequently, a pulling force applied to the body 23 by way of the tow line is transmitted to the guide structure 81 so that it moves in unison with the body 23 by interaction between the protrusion 74 and the rollers 93.

The body 23 incorporates a plurality of holding chambers 100 disposed axially therealong. In this embodiment, there are three such holding chambers 101, 102 and 103.

Each chamber 100 is defined between two spaced apart annular wiper seals 104 and an inner wall 105. The outer periphery of each chamber 100 is exposed directly to the interior surface 13 of the pipeline 15.

Each inner wall 105 is of flexible construction and can be subjected to vibration for the purposes of pressurising contents of the chamber in a pulsating fashion.

In this embodiment, each chamber 100 is adapted to receive resin from the resin supply for the purposes of depositing a layer of resin onto the interior surface 13 of the pipeline 15 prior to application of the liner in position. This further ensures that there is adequate resin for the purpose of wetting out the fibreglass fabric 18.

The chambers 100 operate at different resin pressures; for example, chamber 101 has a higher resin pressure than chamber 102 which in turn has a higher resin pressure than chamber 103. The progressively decreasing resin pressure extending from chamber 101 down to chamber 103. The progressive reduction in resin pressure reduces the likelihood of resin leakage from the installation head 21. Any leakage from chamber 101 (which is at the highest resin pressure) can either be rearwardly towards the everting tube structure 17 (where resin is required in any event) or forwardly into chamber 102 (which is at reduced pressure relatively to chamber 101). Similarly, any leakage from chamber 102 can either be rearwardly to chamber 101 (which is unlikely owing to the higher

pressure in chamber 101) or forwardly to chamber 103 which is at reduced pressure compared to chamber 102. Because chamber 102 is at a reduced pressure, there is little likelihood of leakage from that chamber. If, however, there is leakage from chamber 102 it is unlikely to be of any consequence as it would simply be leakage which deposits resin onto the interior surface 13 of the pipeline 15 where it is required in any event.

The annular seals 104 each comprise a seal face 107 pivotally connected at hinge 109 to the body 23. The seal face 107 is of annular configuration, as is the hinge 109. The hinge 109 is typically is a film hinge.

The seal face 107 is incorporated in an annular seal body 111 which also incorporates an annular inflation chamber 113. The seal face 107 comprises bristles which are forced outwardly for sliding and sealing engagement with the interior surface 13 of the pipeline 15 upon inflation of chamber 113 as the installation head 21 moves along the pipeline. Because the seal face 107 is biased outwardly, it can follow irregularities in the interior surface 13 of the pipeline. When the inflation chambers 113 are deflated, the seals 104 can collapse inwardly so moving the seal faces 107 away from the interior surface 13 of the pipeline. This is particularly advantageous during initial insertion of the installation head 21 into, and removal of the installation head from, the pipeline 15. Because the seals 104 are retracted, they do not engage the interior surface 13 of the pipeline 15 for ease of travel along the pipe when not in operation and during insertion and removal of the installation head 21, so allowing the process to be performed without interference which otherwise might occur through engagement of the seals 104 with the interior surface 13 of the pipeline 15. Once the installation head 21 is in position in the pipeline 15, the various chambers 113 can be inflated so as to move the seal faces 107 into sealing engagement with the interior surface 13 of the pipeline 15.

The installation head 21 may further comprise a series of axially spaced brush devices 115 positioned behind the leading end 27 of the body 23. Each brush device 115 comprises an annular base 116 with bristles 117 projecting therefrom for brushing engagement with the interior surface 13 of the pipeline 15. The brush

devices 115 are linked one to another by way of flexible cables 118. The brush devices 115 are intended to remove debris from the interior surface 13 of the pipeline 15 in order to prepare the surface to receive resin for bonding the liner 11 in position.

A series of chambers 123 are defined between the brush devices 115. The chambers 123 are adapted to contain air at differential pressure such that the air in the trailing chamber is at the highest pressure and the leading chamber at the lowest pressure, with the pressure in the intervening chamber being at an intermediate level such that there is a progressive increase in air pressure from the trailing chamber to the leading chamber. Using this means a flow of air can be generated forwardly from one chamber to the next in the event a fault in the pipeline 15 allows air to leak from one chamber to the next. In the process of moving from one chamber to the next, the air flow will dislodge debris such as sand and gravel particles and displace water resting in any cavities of the pipeline 15 by either blowing it out in front of the installation head 21 for collection or, if there is a hole in the pipeline 15, by displacing the water and debris through the hole to the outside of the pipeline.

Also in this way the lining tool can operate in a pipe that is under the water table by displacing the water by air pressure.

The installation head 21 may further include a collection means 119 for collecting debris within the pipeline 15 prior to installation of the liner 11. The collection means 119 comprises a suction system having a suction head 120 connected to a suction line 122.

The apparatus 10 can be equipped with various sensing and monitoring devices to facilitate regulation of the installation process for the liner 11 with the objective of establishing and maintaining optimum conditions therefor. Such sensing and monitoring devices may include means for conducting visual inspections of the pipeline 15 prior to, during, and/or after the installation process. Additionally, such devices may permit a determination to be made as to the extent (if any) of cleaning required for the pipeline surface.

Further, such devices may enable calculation of the optimum volumetric quantities and delivery rates for the resin. In this way, delivery of the resin can be controlled to allow application of appropriate quantities. Thus, the delivery rates (and hence volume) of resin can be regulated on an ongoing basis during the installation process where, for example, it may be necessary to apply more resin at some locations than at other locations because of variations in the pipeline condition along its length. As well as avoiding wastage of resin, this may also allow the installation speed to be increased at locations where reduced resin quantities are required.

Still further, the sensing and monitoring devices may allow optimum curing conditions for the resin to be determined, having regard to factors such as, for example, temperature and humidity. This may permit the composition of the resin to be varied as necessary in an endeavour to provide optimum curing conditions, by for example adding, removing or varying the quantity of components such as accelerators, activators and/or catalysts.

Other sensing and monitoring devices may include sensors for measuring the strain and load on the everting liner.

The use of the sensing and monitoring devices facilitates ongoing, or at least regular, feedback for maintenance of optimum installation conditions. This enhances the reliability of the installation process.

Operation of the apparatus 10 installing the liner 11 in the pipeline 15 will now be described.

The installation head 21 is positioned within the pipeline 15 adjacent the end thereof at which the lining operation is to commence. The leading end 27 of the body 23 is connected to a tow line which extends to the other end of the pipeline and terminates at a station at which various operations are performed including retraction of the tow line in order to pull the installation head 21 along the pipeline. The installation duct 34 is positioned adjacent the commencement end of the pipeline 15 and the delivery structure 37 is installed at a convenient location,

typically at ground level in the vicinity of the end of the pipeline. The delivery duct 35 is then positioned between the installation duct 34 and the delivery structure 37. Because of its flexible nature, the delivery duct 35 can conveniently follow an access path dug in the ground leading to the end of the pipeline. The tube structure 17 is then passed in a collapsed condition through the entry end 45 of the delivery chamber 39 within the delivery structure 37 and along the delivery duct 35 to project beyond the installation duct 34. The leading end of the collapsed tube structure 17 is then connected to the installation duct 34 by way of a clamping collar which extends around the tube and sealingly connects it to the end of the duct 34. Fluid pressure is then introduced into the delivery chamber 39 and the delivery duct 35, so as to inflate the delivery duct 35 and commence eversion of the tube structure 17. As the tube structure 17 commences to evert, its everting portion 33 is presented to, and guided into the end of the pipeline 15 so that the tube advances along the pipeline as it everts.

As the everting tube advances along the pipeline, it embraces the lance 73, and the everting portion 33 engages the pressure plate 65 at the trailing end of the body 23. The rate of advancement of the everting tube structure 17 along the pipeline 15 is controlled by the rate at which the installation head 21 itself travels, with the everting face 33 of the tube structure 17 being in wiping contact with the contact face 63. Because the contact pressure exerted by the everting tube structure 17 is directed onto the pressure plate 65, the resin itself is not pressurised and can flow freely through the apertures 71 and into the space bounded by the pressure plate 65 and the everting portion 33 of the tube structure 17. Resin within the resin chamber 67 passes through the apertures 71 in the pressure plate 65 and so contacts the everting portion of the tube structure 17 to impregnate the fibreglass layer thereof. The fibreglass layer is also wetted with resin through exposure to resin at the nose 75 of the lance 73. As the installation head 21 advances along the pipeline 15, resin is applied to the interior surface 13 of the pipeline by way of the chambers 100.

Because of the various locations at which resin is presented to the fibreglass layer of the tube structure 17 by the time it contacts the interior surface 13 of the pipeline 15, optimum resin impregnation of the fibreglass fabric is achieved.

Inflation pressure within the everting tube structure 17 presses the outer portion 32 of the tube structure 17 into intimate contact with the interior surface 13 of the pipeline 15. The process continues until the installation head 21 reaches the other end of the pipeline 15, where it can be withdrawn from the pipeline and the surplus end section of the tube structure 17 clamped to the pipeline 15 so as to close the end of the inflation chamber 41 and thereby maintain inflation pressure within the everted tube structure 17 until such time as the resin sets to form a composite structure in co-operation with the fibreglass fabric.

In the first embodiment, there was a mechanical connection between the body 23 and the guide structure 81 by virtue of interaction between the protrusion 74 and rollers 93 for the purposes of moving the guide ring structure 81 along the pipeline 15 in unison with the body 23.

In an alternative arrangement, there is may be an electromagnetic connection between the body 23 and the guide structure 81 for such purpose. The electromagnetic interconnection may be the sole connection therebetween or it may be augment a mechanical connection of any appropriate type such as that described in relation to the first embodiment.

The second embodiment, which is illustrated in Figure 10 of the drawings, uses an electromagnetic connection between the body 23 and the guide structure 81. The electromagnetic connection comprises an electromagnet 121 positioned on the pressure plate 65 on the side thereof opposite the contact face 63. With this arrangement, the electromagnet 121 is accommodated within the resin chamber 67. The electromagnet 121 incorporates apertures 123 which align with corresponding apertures 71 in the pressure plate 65 so as not to interfere with flow of resin from the resin chamber 67 to the contact face 63.

A particular advantage of the electromagnetic connection is that the gap between the contact face 63 and the guide surface 85 of the guide structure 81 can be selectively varied by virtue of the intensity of the magnetic field which is established. In this way, the drag imposed on the tube 13 by the installation head 21 as it advances along the passageway 15 can be regulated. This information

can be incorporated into a direct feed back loop so that the process and the thickness of the resin contained between the face and the ring can be controlled .

In this embodiment, the installation head is equipped not only with the electromagnetic connection but also the mechanical connection provided by interaction between the rollers 93 supported on the guide structure 81 and the protrusion 73 provided on the lance 73 projecting rearwardly from the body 23. In this way, the connection between the guide ring 81 and the body 23 is maintained even when the electromagnetic connection ceases.

In the first and second embodiments, the tube structure 17 everted around a guide structure 81. It should, however, be appreciated that the guide structure may not be necessary in certain applications. The action of fluid pressure within the everting tube structure 17 may be sufficient to cause eversion of the tube and advance the tube along the pipeline. The rate of advancement of the everting tube along the pipeline is controlled by the rate at which the installation head 21 itself travels, with the everting face 33 of the tube structure 17 being in wiping contact with the contact face 63. Such an arrangement is illustrated in Figure 11 of the drawings.

The installation head 21 may be equipped with a mechanism 130 for extracting air from cavities which might exist on the upper part of the top part of the interior surface 13 of the pipeline. Such an arrangement is incorporated in the embodiment illustrated in Figures 12 and 13 and includes a suction line 131 having a suction end 133. The suction line 131 adjacent the suction end 133 is configured at 135 to function as a spring arrangement biasing the suction end to an outermost condition projecting beyond the periphery of the body so as to be capable of entering cavities in the top section of the pipeline 15, as illustrated in Figure 13 where it is seen that the suction end 133 has entered cavity 139. Normally, the suction end 133 is retained in a retracted condition as shown in Figure 12, by virtue of contact with the interior surface 13 of the pipeline 15. However, when the suction end 133 encounters a cavity (such as cavity 139 as shown in Figure 13), the suction end 133 can project outwardly and enter the cavity.

The suction end 33 is slightly offset from normal to the surface 13 of the pipeline, with the orientation being away from the direction of movement of the installation head, so as to avoid jarring or catching on the pipeline surface 13.

Referring now to Figures 14 to 17, there is shown apparatus 10 according to a further embodiment for installing a liner 11 onto the interior surface 13 of a pipeline 15.

The apparatus according to this embodiment is similar to the apparatus 10 according to the first embodiment, and so corresponding reference numerals are used to identify corresponding parts, where appropriate. In this embodiment, the delivery chamber 39 incorporates guide rollers 141 against which the collapsed tube structure 17 engages. The guide rollers 141 assist tracking of the tube structure 17 as it enters the delivery duct 35.

A roller assembly 143 is provided adjacent the end of the delivery duct 35 for the purposes of aligning the tube structure prior to entry thereof into the installation duct 34. The roller structure 143 comprises a pair of rollers 145 between which the collapsed tube structure 17 passes, with the longitudinal side portions 18, 19 of the collapsed tube structure in engagement with the rollers 145. The roller assembly 143 incorporates a lateral guide roller 147 against which one of the longitudinal edges of the collapsed tube structure 17 engages. The guide roller 143 assembly assists with lateral tracking of the collapsed tube structure as it enters the installation duct 34.

Referring now to figure 18 of the drawings, there is shown a delivery chamber 39 for an installation apparatus according to a still further embodiment. The delivery chamber 39 for this embodiment is similar to the delivery chamber of the previous embodiments, with the exception that it incorporates two fluid seal mechanisms 49, rather than one such fluid seal mechanism as was the case with the earlier embodiment.

Referring now to Figures 19 to 25 of the drawings, there is shown installation apparatus 10 according to a still further embodiment. Again, where similarities

exist with earlier embodiments, corresponding reference numerals are used to identify corresponding parts. The installation apparatus 10 according to this embodiment comprises an installation head 21 somewhat similar to the installation head of the first embodiment. In the first embodiment, the installation head 21 was described as being drawn along the pipeline 15 by a towline. In certain applications, the installation head 21 may be advanced not by a towline but rather by a driving force applied to it by the everting tube structure 17. Specifically, inflation fluid pressure, which is introduced into chamber 20 within the tube structure for causing eversion thereof and also for pressing the outer portion 32 of the tube structure into intimate contact with interior surface 13 of the pipeline 15, may be sufficient to apply a driving force to the installation head 21 through the pressure plate 65 which the everting tube structure 17 contacts. In such circumstances, there may be a need to have a mechanism for retarding the rate at which the installation head 21 advances under the influence of the fluid pressure applied through the everting tube structure 17. For this purpose, the installation head 21 according to this embodiment incorporates a brake sled 151. The brake sled 151 is located ahead of the installation head 21 and is connected thereto by way of a rigid coupling 153 for transference of a retarding force from the brake sled 151 to the installation head 21.

The brake sled 151 is adapted to frictionally engage the interior surface 13 of the pipeline 15 so as to provide the retarding force. The retarding force can be selectively varied by regulating the extent of frictional engagement with the interior surface 13 of the pipeline 15, as will be explained shortly. Furthermore, the retarding force is also regulated by having a mechanism for driving the brake sled 151, the arrangement being that the rate of advancement of the brake sled 151 (and hence the installation head 21 to which it is rigidly coupled) can be controlled by selectively varying the driving force applied to the brake sled. In other words, the rate at which the brake sled 151 and installation head 121 advance in unison is determined by a balance between: (1) the force applied to the installation head 21 through the everting tube structure 17 by the inflation fluid; (2) the driving force applied to the brake sled; and (3) the retarding force exerted on the brake sled 151 through frictional engagement with the pipeline 15.

In this embodiment, the brake sled 151 is driven by applying a towing force thereto through a towline 157, one end of which is coupled to the brake sled at coupling point 158 and the other of which is connected to a hauling mechanism such as a winch (not shown).

The brake sled 151 comprises three skid members 161, 162 and 163, each adapted to be located in sliding engagement with the interior surface 13 of the pipeline 15. Skid member 161 functions as the base of the brake structure 151 and travels along the bottom of the pipeline 15. The skid members 162 and 163 are supported on base skid member 161 by booms 165, 167. Boom 165 incorporates an adjustment mechanism 169 for selectively varying the effective length thereof and thus the relative position of skid member 162. In this way, the spacing between the three skid members 161, 162 and 163 can be varied, thus regulating the radial positioning of the skid members and consequently the force with which they frictionally engage the interior surface 13 of the pipeline 15.

In this embodiment, base skid member 161 comprises a tubular member 171 filled with ballast material such as lead. The leading end of the tubular member is upturned, and a longitudinal web 173 is provided along the length of the tubular member.

Skid members 162, 163 each comprise an elongate element 175 being in-turned at the leading end thereof. Each elongate element 175 is provided with a covering 177 formed of friction material (such as tyre tread) for the purpose of enhancing frictional resistance with the interior surface 13 of the pipeline 15.

The installation head 21 according to the embodiment also incorporates a suction mechanism 130 for extracting air from cavities which might exist on the upper part of the interior surface 13 of the pipeline 15, as was the case with the first embodiment. The suction mechanism 130 in this embodiment comprises a suction line 181 having a suction end 183. The suction line 181 adjacent the suction end 183 incorporates a formation 185 which causes the outer end section 187 of the suction line 181 to deflect laterally to extend beyond the periphery of

the installation head so as to be capable of entering cavities in the upper part of the pipeline 15, as shown in Figure 22 of the drawings where the end section 187 is shown in cavity 188. The formation 185 in the suction line 181 establishes a "kink" in the suction line 181 when the outer section 187 is not deflected laterally, as shown in Figure 21 of the drawings. The "kink" functions as a valve for the purposes of stopping, or at least retarding, flow into the suction line 181 in circumstances where air extraction is not necessary (ie. where there is no cavity).

This embodiment also incorporates the feature of a clamping seal mechanism 191 for clampingly retaining the outer tube portion 32 in sealing engagement with the interior surface of the pipeline 15. This is for the purpose of blocking rearward flow of resin to ensure that there is an ample coating of resin between the interior surface 13 of the pipeline 15 and the outer tube portion 32 in the section 193 thereof immediately rearward of the everting portion 33 of the tube structure 17. With this arrangement, the resin is contained at one end by the clamping seal mechanism 191 and at the other end by the pressure plate 65 and the annular seal 104 therearound. This ensures that there is ample resin between the interior surface of the pipeline 15 and the section 193 of the liner rearward of the everting portion 33 for bonding purposes.

The clamping seal mechanism 191 comprises a support 194 of split ring construction, incorporating a mechanism 196 for expanding and contracting the ring. The outer surface of the support 194 is provided with a layer 198 of deformable material, such as rubber, for the purposes of accommodating irregularities in the surface against which it bears. The split-ring support 194 is moved into a contracted condition so as to allow it to be fitted in position in the pipeline 15. It is then expanded to clampingly engage against the interior surface of the pipeline 15, with the outer tube portion 32 clamped therebetween.

In the installation head 21 used in the first embodiment, the pressure plate 65 defining the contact face 63 was rigidly supported within the installation head. In this embodiment, the pressure plate 65 is supported on an elastic suspension system 201 incorporating a spring 203. This allows the pressure exerted on the

pressure plate 65 through the everting tube portion 33 by the inflation fluid to be monitored and operating systems adjusted accordingly. For example, the rate of delivery of resin to the resin chamber 67 can be varied by regulating the resin delivery pump according to operating demands as determined by the pressure. In this embodiment, this arrangement involves use of a proximity switch (not shown) which detects deflection of the pressure plate 65 to a prescribed extent in response to pressure exerted thereon, so as to initiate delivery of resin to the resin chamber 67. In this way, delivery of resin to the resin chamber 67 can be stopped, or at least reduced, in the event of separation between the contact face 63 of the pressure plate 65 and the everting portion 33 of the tubular structure 17. The resin flow can recommence once the everting portion 33 of the tubular structure 17 moves into appropriate contact with the contact face 63, as determined by deflection of the pressure plate 65.

The embodiment shown in Figures 26, 27 and 28 is directed to apparatus 10 according to a still further embodiment for installing a liner 11 onto the interior surface 13 of a pipeline 15. The apparatus 10 according to this embodiment is similar in most respects to the apparatus 10 according to the first embodiment and corresponding reference numerals are used to identify corresponding parts. In this embodiment, there is provision for hauling the collapsed tube structure 17 along the delivery duct 35 and installation duct 34, as well as the pipeline 15, to augment the advancing movement effected by the inflation pressure.

The haulage system utilises an installation cable 211 in the form of a haul rope. The haul rope 211 extends axially through the tubular structure 17, such that the tubular structure binds to the rope when the tubular structure is in its collapsed condition. While not apparent from the drawings, in this embodiment the tubular structure comprises an inner layer 17a and an outer layer 17b, with the rope 211 extending axially along the tubular structure within the inner 17a layer. The rope 211 is inserted into position in the tubular structure 17 at the time of manufacture of the tubular structure 17.

The rope 211 is hauled by an appropriate hauling mechanism, such as a winch or winding drum (now shown).

In this embodiment, the lance 73 projecting rearwardly from the pressure plate 65 terminates at a protrusion 74 which is of generally spherical configuration. It may be advantageous for the lance 73 to have some lateral flexibility. The protrusion 74 is received in the collapsed interior of the tubular structure 17 between the longitudinal side portions 18, 19 thereof as the tubular structure approaches the installation head. The lance 73 has a passage 221 extending axially therethrough. The passage 221 is dimensioned to receive the rope 211 with a clearance space 223 therebetween, as best seen in Figure 28 of the drawings. With this arrangement, the lance 73 assists in separating the haul rope 211 from the collapsed tubular structure 17, with the rope 211 passing through the lance 73 and the longitudinal portions 18, 19 moving to opposed sides of the lance as they approach the contact face 63 of the pressure plate 65, also as best seen in Figure 28 of the drawings.

The clearance space 223 provides a passage through which any air within the collapsed tubular structure 17 can escape.

Because the collapsed tubular structure 17 binds to the rope 211 and is separated therefrom through interaction with the lance 73, the rope and tubular structure advance at the same rate along the delivery duct 35 and installation duct 34.

Because the rope 211 is drawn through the central passage 221 within the lance 73 and is connected to a hauling mechanism such as a winch, it moves independently of the installation head 21.

While the embodiment shown in Figures 26, 27 and 28 is designed specifically for use with a tubular structure 17 incorporating a haul rope 211, it can also be used with a tubular structure which does not incorporate such a haul rope. Use of the installation head according to the embodiment with a tubular structure 17 without a haul rope is illustrated in Figure 29 of the drawings.

In the embodiments described previously, the tubular structure 17 was delivered to installation head 21 in a collapsed condition as shown in Figure 9 of the drawings.

It has been found that there is an advantage in folding the tubular structure 17 into a collapsed condition involving one or more re-entrant folds. Such a folded condition is illustrated in Figure 30 of the drawings, where the tubular structure 17 comprises an inner tubular layer 17a and an outer tubular layer 17b. In this embodiment, the inner tubular layer 17a is of a resin absorbent material such as fibreglass fabric, and the outer tubular layer 17b is of a material appropriate for the intended purpose, such as polypropylene.

The tubular structure 17 is folded into a collapsed condition involving two re-entrant folds 231, 232 disposed between two longitudinal side portions 233, 234. With this arrangement, the re-entrant folds each extend inwardly from one longitudinal edge of the collapsed tubular structure. Again, it should be noted that the longitudinal portions 18, 19 are illustrated in Figure 30 in a spaced apart condition, however, in practice they would be in facing contact.

Such a folding structure has been found to be particularly advantageous in the manner in which it undergoes eversion. This will be explained with reference to Figures 31 and 32, where Figure 31 is a schematic view of the everting portion 33 of the collapsed tubular structure shown in Figure 30, and Figure 31 is a view of the everting portion of the collapsed tubular structure shown in Figure 9. It can be seen from Figure 31 that the tube structure 17 everts in a nearly even manner, with imaginary chords 235 along the surface 237 of the everting portion travelling about the same distance and in a relatively even direction radially in moving from the collapsed condition to the assembled condition. By comparison, it is evident from Figure 32 that the collapsed tubular structure shown in Figure 13 does not evert in such an even fashion.

The collapsed tubular structure shown in Figure 30 has two re-entrant folds. It should be appreciated that other folding patterns involving re-entrant folds are

possible. For example, Figure 33 illustrates a collapsed tubular structure involving a plurality of re-entrant folds extending inwardly from each longitudinal edge thereof.

Referring now to Figures 34, 35 and 36, there is shown a construction of the tubular structure 17 having provision for extraction of air contained therein. The arrangement comprises a sleeve 241 formed of a flexible plastic material or any other appropriate material impermeable to air. The sleeve 241 encases the collapsed tubular structure 17. Figure 34 illustrates the arrangement in a very schematic fashion which does not truly resemble the actual appearance. In reality, the tubular structure 17 is collapsed such that the longitudinal portions 18, 19 are pressed one against the other in facing contact, with the re-entrant folds compressed therebetween. Furthermore, the sleeve 241 tightly encases the collapsed tubular structure 17. Longitudinal spacer elements 243 extend axially along the collapsed tubular structure 17 between longitudinal portion 18 and the encasing sleeve 241. In this embodiment, the longitudinal elements 243 comprise a bundle of fibreglass strands. The longitudinal elements 243 cooperate with the collapsed tubular structure and the encasing sleeve to establish an axial path 247 along which air can be extracted. Typically, the axial air path 247 is established with the bundle of fibreglass strands. The axial path 247 communicates with suction source (not shown) at the trailing end of the collapsed tubular structure 17. As shown in Figure 35, the collapsed tubular structure 17 is delivered from a reel 251 about which it is wound. The reel 251 has provision 253 for coupling the end of the air path 247 to the suction source.

Various embodiments described previously utilise a tube structure 17 having an inner layer 17a and an outer layer 17b. Figures 37 to 44 of the drawings illustrate an arrangement for conveniently constructing such a tube structure 17.

The arrangement comprises an assembly line 250 at which various operations of the construction process can be performed. The assembly line has a first end 251, a second end 252, and a construction path extending between the first and second ends. At the first end 251, various materials used in the construction

process can be delivered to the construction path from respective reels on which the materials are supplied. At the second end 253, the constructed component can be wound onto a storage reel 257. The storage reel 257 is driven to facilitate winding of the component thereonto.

The construction path has various operational stages, comprising a first forming stage 261, a second forming stage 262, a bonding stage 263 and a fourth folding and pressing stage 264. In this embodiment, the second and third stages 262, 263 are integrated in a single unit 267.

The first stage 261 involves a former 269, as shown in Figure 38 of the drawings. The former 269 comprises a outer member 271 incorporating an aperture 273 located therein. A loop member 275 is accommodated within the aperture 273 in spaced apart relationship from the periphery thereof, such that there are two working spaces 281, 282 defined within the former. The space 281 is defined between the outer member 271 and the loop member 275, and the space 282 is defined within the confines of the loop member 275, as shown in Figure 37.

Construction of the inner layer 17a of the tubular structure 17 will now be described with reference to Figures 39 and 40 of the drawings. A roll 290 of fibreglass material is located at the first end 251 and a web 291 of material therefrom is fed along the construction path, passing in the outer space 281 within the former 269, as shown in Figure 40 of the drawings. In this way, the longitudinal edge portions of the web 291 of fibreglass material are turned inwardly towards each other, in the first step of the process of forming the web into a tubular configuration. From the first former 269, the web 291 (with the longitudinal sides thereof turned inwardly) continues to travel along the construction path towards a second former at second stage 262 at which the longitudinal edges are positioned one with respect to the other for bonding together. The bonding action is performed at the bonding stage 263. For construction of the inner layer 17a, the bonding process typically involves adhesive bonding. This completes construction of the inner portion in its tubular form, and it is then wound onto a storage reel 293 at the second end 252.

The next stage of the process involves transferring the reel 293 on which the inner layer 17a is wound to the first station 251. A web 295 of material for the outer layer 17b is to be constructed on a reel 297 also at the first station. The tubular inner layer 17a is fed into the inner space 282 within the former 269, and the web 295 of material to provide the outer layer 17b is fed into the outer space 281 within the former 269, as best shown in Figure 42. As the materials travel through the former 269, the longitudinal side portions of the web 295 contained within the outer space 281 are turned inwardly to commence construction of the outer layer 17b in its tubular configuration. From the first former, the materials travel to the second former at station 262 at which the longitudinal edges of the web 295 are brought together and bonded one to another so as to complete construction of the outer layer 17b in its tubular configuration. This thus provides the tubular structure 17 having the inner and outer portions. The bonding process in construction of the outer layer 17b typically involves plastic welding.

Where the tubular structure 17 is to have a collapsed configuration as shown in Figure 9, the construction process continues to stage 264 where the collapsed tubular structure is compressed to ensure that bonded surfaces are in good contact one with the other and to also flatten the tubular structure to facilitate winding onto a reel 299 at the second station.

In circumstances where the tubular structure 17 is to have re-entrant folds, such as illustrated in Figures 30 and 33, the tubular structure 17 is subjected to a folding operation. This can be conducted prior to winding of the tubular structure onto the reel 299, or alternatively as a separate operation at a later stage.

Where the tubular structure 17 incorporates a haul rope 211 as described earlier in relation to the embodiment shown in Figures 26, 27 and 28, the haul rope 211 can be incorporated into the tubular structure 17 during construction thereof. Specifically, the haul rope 211 can be positioned within the inner tubular layer 17a during its construction. This can be seen with reference to Figures 43 and 44 of the drawings, which illustrates construction of the inner layer 17a. The rope 211 is provided on a reel 301 and is fed into the inner space 282 within the first former

269, with the web 291 of material providing the inner layer 17a passing through the outer space 281, as shown in Figure 44. In this way, the inner layer 17a is formed around the rope 211.

It is likely that the installation heads 21 according to the previous embodiments will require a plurality of service lines 310 for provision of services such as electrical power, resin supplies, and a winching cable, as shown in Figure 46. The service lines 310 extend to the installation head 21 from a station 311 located exteriorly of the pipeline at the end thereof which the installation head 21 approaches during the lining operation. The station 311 accesses the underground pipeline 15 by way of access hole 313 in the ground 315. As the installation head 21 approaches the end, the necessary length of each service line progressively reduces and so surplus service line is wound onto reels. In certain circumstances, it may be advantageous to contain that lengths of the surface lines within the pipeline within a containment sleeve 320, for the purposes of avoiding tangling and other interference between the various surface lines. This can be achieved by way of the containment sleeve 320 as illustrated in Figure 45 of the drawings. The containment sleeve 320 may be formed of a plurality of sleeve sections 321 adapted to be zipped one to another by zippers 323 to form the sleeve. The sleeve sections 321 can be progressively unzipped as the sleeve 320 approaches the station 311, thereby allowing the various service lines 310 to separate for winding onto their respective reels 311. Such a sleeve 320 constructed of sleeve sections zipped together may be in the form of a shroud of the type described in US Patent 6,196,766. The haul rope 211 (if employed) is not accommodated in the containment sleeve 320.

Improvements and modifications may be incorporated without departing from the scope of the invention.

In the various embodiments described, each chamber 123 was adapted to contain air. In an alternative embodiment, the trailing chamber 123 may be adapted to receive and contain nitrogen (or another appropriate gas or gaseous mixture) to

displace air and thus provide an inert environment to which the resin is exposed as it is subsequently applied.

From the foregoing, it is evident that the present embodiments provide a simple yet highly effective arrangement for ensuring that the everting tube is properly "wet-out" during installation of the liner 11.

Improvements and modification may be incorporated without departing from the scope of the invention.

Throughout the specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

Dated this sixteenth day of May 2003.

Shieldliner Co Limited
Applicant

Wray & Associates
Perth, Western Australia
Patent Attorneys for the Applicant

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

☒ **BLACK BORDERS**

☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**

☐ **FADED TEXT OR DRAWING**

☒ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**

☐ **SKEWED/SLANTED IMAGES**

☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**

☐ **GRAY SCALE DOCUMENTS**

☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**

☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**

☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.